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Numerical Analysis of Micro strip Patch Antenna Array

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ABSTRACT - This paper present simple, slim, low cost and high gain rectangular patch microstrip array antenna, operating at 10 GHz have numerically analyzed. The method of analysis is carried out for 4x1 arrays. The radiation patterns of single patch element and patch antenna array are simulated by MATLAB program and also compared. Beacause of its versatility, array can be used to synthesize a required pattern that cannot be achieved with a single patch element.

KEYWORDS- Microstrip Patch Antenna; Antenna arrays; E-field equation; H-field equation; radiation patterns.

I. INTRODUCTION

Microstrip patch antennas consist of very thin metallic strip (patch) placed a small fraction of wavelength above a ground plane. The patch is designed so its pattern maximum is normal to the patch. For a rectangular patch, the length L of the element is usually $\lambda_o/3 <$ L$< \lambda_o/2$. The patch and the ground plane are separated by a dielectric substrate as shown in Figure-01.

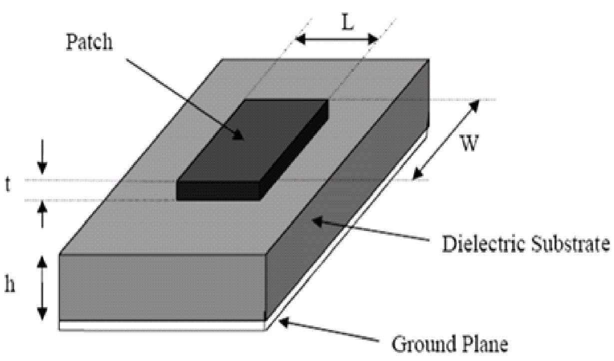

Figure 1: Microstrip patch antenna

Microstrip antennas have several advantages compared to conventional microwave antennas therefore many applications cover the broad frequency range from 100 MHz to 100 GHz.

Some of the principal advantages compared to conventional microwave antennas are:
• Light weight, low volume, end thin profile configurations, which can be made conformal.
• Low fabrication cost.
• Linear, circular and dual polarization antenna can be made easily
• Feed lines and matching networks can be fabricated simultaneously with the antenna
However microstrip antennas also have limitations compared to conventional microwave antennas:
• Narrow bandwidth and lower gain
• Most microstrip antennas radiate into half space
• Polarization purity is difficult to achieve
• Lower power handling capability.
There are numerous substrates that can be used for the design of microstrip antennas and their dielectric constants are usually in the range of 2.2 $\leq \varepsilon_r \leq$12 that are used in wireless applications. Those with high dielectric constants are more suitable for lower frequency applications in order to help minimize the size.

1. EXPRESSIONS OF E-FIELD AND H-FIELD OF PATCH ANTENNA

The magnetic field intensity and electric field intensity can be expressed as

$$E_\Phi = \eta H_\theta = \frac{jk_o I_m hw}{4\pi r} e^{-jk_o r} \sin\left(k_o w \frac{\cos\theta}{2}\right) \frac{\sin\theta}{k_o w \frac{\cos\theta}{2}} \quad (1)$$

$$H_\theta = \frac{jk_o I_m hw}{4\pi \eta_o} e^{-jk_o r} \sin\left(k_o w \frac{\cos\theta}{2}\right) \frac{\sin\theta}{k_o w \frac{\cos\theta}{2}} \quad (2)$$

2. EXPRESSIONS OF E-FIELD AND H-FIELD OF 4-ELEMENTS PATCH ANTENNA ARRAY

The figure 2 shows a rectangular patch antenna array of 4-elements separated from each other by a distance d.

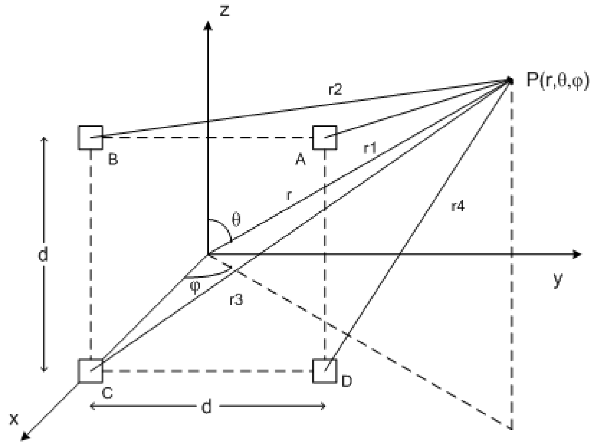

Figure 2: Patch Antena Array

Using equation (1) the electric field intensity can be written as

$$E_\Phi = \eta H_\Theta = \frac{jk_o I_m hw}{4\pi r} e^{-jk_o r} \sin(k_o w \frac{\cos\Theta}{2}) \frac{\sin\Theta}{k_o w \frac{\cos\Theta}{2}}$$

Assuming, $\theta_1 = \theta_2 = \theta$

The co-ordinates of, A= (0, d/2, d/2)

B= (0, d/2, d/2)

C= (0, d/2, d/2)

D= (0, d/2, d/2)

Let, the co-ordinates of P= (r, θ, φ)

So , x= r sinθ cosφ

y= r sinθ sinφ

z= r cosθ

The distances from the patch elements to the far field point, *p* can be approximated as

$r_1^2 = r^2 \sin^2\theta \cos^2\varphi + (r \sin\theta \cos\varphi - d/2)^2 + (r \cos\theta - d/2)^2$

$= r^2 + d^2/2 - rd (\sin\theta \sin\varphi + \cos\theta)$

$= r^2 \{1 + d^2/2r^2 - d/r (\sin\theta \sin\varphi + \cos\theta)\}$

$r_1 = r \{1 - d/r (\sin\theta \sin\varphi + \cos\theta)\}^{1/2}$

$r_1 = r - d/2 (\sin\theta \sin\varphi + \cos\theta)$

Similarly,

$r_2 = r + d/2 (\sin\theta \sin\varphi - \cos\theta)$

$r_3 = r + d/2 (\sin\theta \sin\varphi + \cos\theta)$

$r_4 = r - d/2 (\sin\theta \sin\varphi - \cos\theta)$

Now for 4-elements the electric field intensity can be written as

$$E_\Phi = A\{\frac{e^{-jk_o r}}{r} + \frac{e^{-j(k_o r_1 - \beta)}}{r_1} + \frac{e^{-j(k_o r_2 + \beta)}}{r_2} + \frac{e^{-j(k_o r_3 + \beta)}}{r_3} + \frac{e^{-j(k_o r_4 - \beta)}}{r_4}\}$$

$$\text{Where, } A = \frac{jk_o I_m hw}{4\pi} \sin(k_o w \frac{\cos\theta}{2}) \frac{\sin\theta}{k_o w \frac{\cos\theta}{2}}$$

$$E_\Phi = A\{\frac{e^{-jk_o r}}{r} + \frac{e^{-j(k_o\{r - \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta)\} - \beta)}}{r_1} + \frac{e^{-j(k_o\{r + \frac{d}{2}(\sin\theta\sin\varphi - \cos\theta)\} + \beta)}}{r_2} + \frac{e^{-j(k_o\{r + \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta)\} + \beta)}}{r_3} + \frac{e^{-j(k_o\{r - d/2 (\sin\theta\sin\varphi - \cos\theta)\} - \beta)}}{r_4}\}$$

Assuming that, $r \gg d \sin\theta\sin\Phi$

$$E_\Phi = A\frac{e^{-jk_o r}}{r}\{1 + e^{j\{k_o \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta) + \beta\}} + e^{-j(k_o \frac{d}{2}(\sin\theta\sin\varphi - \cos\theta) + \beta)} + e^{-j\{k_o \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta) + \beta\}} + e^{j\{k_o d/2 (\sin\theta\sin\varphi - \cos\theta) + \beta\}}$$

Finally the electric field equation for 4-elements array can be written as

$$E_\Phi = A\frac{e^{-jk_o r}}{r}[1 + 2\cos\{k_o \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta) + \beta\} + 2\cos\{k_o \frac{d}{2}(\sin\theta\sin\varphi - \cos\theta) + \beta\}] \quad (3)$$

The magnetic field equation for 4-elements array using (3) can be written as

$$H_\theta = {E_\Phi}/{\eta} = \{A\frac{e^{-jk_o r}}{r}[1 + 2\cos\{k_o \frac{d}{2}(\sin\theta\sin\varphi + \cos\theta) + \beta\} + 2\cos\{k_o \frac{d}{2}(\sin\theta\sin\varphi - \cos\theta) + \beta\}]\}/\eta \quad (4)$$

3. RADIATION PATTERNS OF SINGLE PATCH ANTENNA

Radiation patterns of E-field and H-field are plotted using equations (1) and (2) which are shown in figure 3 and figure 4 using MATLAB program:

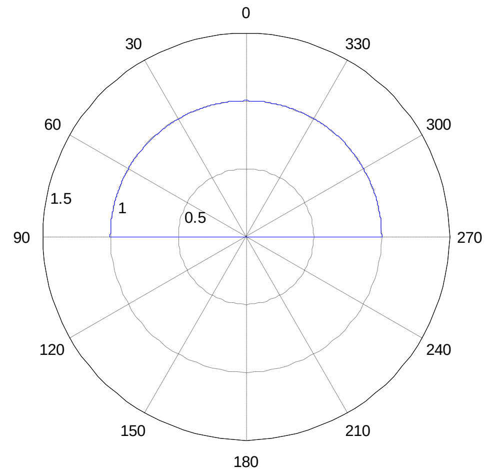

Figure 3: E-field radiation pattern

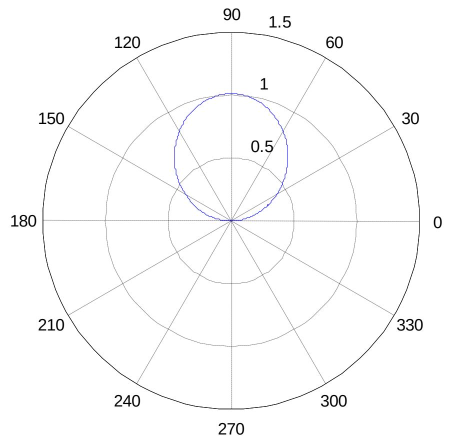

Figure 4: H-field radiation pattern

4. RADIATION PATTERN OF 4-ELEMENTS PATCH ANTENNA ARRAY

Radiation pattern of E-field and H-field are plotted using equations (3) and (4) which are shown in figure-05 and figure-06 using MATLAB program:

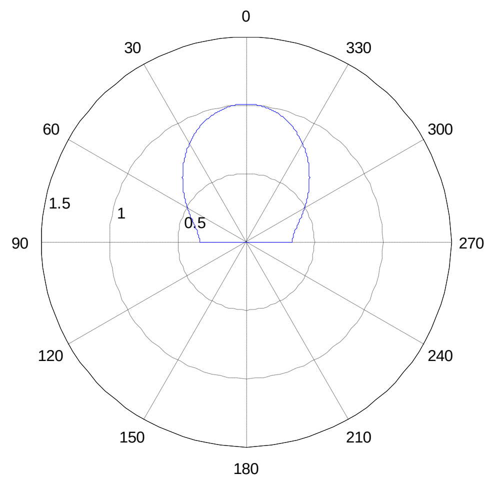

Figure 5: E-field radiation pattern

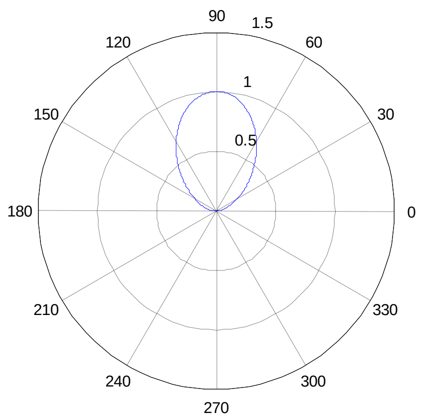

Figure 6: H-field radiation pattern

5. DISCUSSIONS AND CONCLUSIONS

The microstrip patch antenna has been numerically analyzed for both single patch antenna and four elements patch antenna array. The radiation patterns for H-field for both single patch antenna and four elements patch antenna array are nearly same. But the radiation pattern for the E-field of four elements patch array is more concentrated than the single patch antenna. So the gain and directivity is increased. Thus increasing the number of patches or elements enhances the performance of the antenna. The investigation has been limited mostly to the numerical analysis only. Detailed experimental studies can be taken up at a later stage for the simulation and fabrication of the antenna.

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